REVIEW OF THE KEY RESULTS OF A LARGE INTEGRATED AIR QUALITY PROJECT IN AUSTRALIA

T. Banhazi

National Centre for Engineering in Agriculture (NCEA), Faculty of Engineering and Surveying, University of Southern Queensland (USQ), Toowoomba QLD, 4350

SUMMARY

It was established that improvement in air quality in livestock buildings could produce significant benefits for animals, workers and the environment. In order to achieve a sustained reduction in the concentration of airborne pollutants in livestock building; the different management, environmental and housing factors, which could influence the concentrations within and emissions of airborne pollutants from livestock buildings had to be statistically evaluated. Thus a broad study of air quality in piggery buildings was designed (1) to determine the key piggery design and management factors that affect the internal concentrations and emissions of airborne pollutants and then to (2) model and therefore able to predict the concentrations and emission rates of the main pollutants. This article considers the implications of the main results of this significant research project.

INTRODUCTION

The significant amounts of airborne pollutants, which can be found in the airspace of some piggery buildings could potentially affect the external environment, production efficiency of pigs, human as well as animal health and welfare (Banhazi *et al.*, 2009). In order to achieve the maximum safe concentrations recommended in Australia a broad study of air quality in piggery buildings was designed (1) to determine the key piggery design and management factors that affect the internal concentrations and emissions of airborne pollutants and then to (2) model the concentrations and emission rates of the main pollutants. This article is a summary of the main results of this national research project.

MATERIAL AND METHODS: BRIEF DESCRIPTION OF STUDY DESIGN

To enable this study to be conducted, the sampling methods and instrumentation kit used during the survey was standardised and an "environmental monitoring kit" (EMK) was developed. In the later stage of the study the original EMK was further simplified, so it could be used as an extension tool after the completion of the survey component of the study (Banhazi, 2009). A field survey of airborne pollutant concentrations within and emissions from 160 piggery buildings in four states of Australia was then executed. The measurement techniques chosen proved to be practical, reliable and cost effective (Banhazi *et al.*, 2008b; Banhazi *et al.*, 2008c). Using the collected data, comprehensive statistical modelling was undertaken to explain the variation in the measured concentrations and emission rates. An output from this component of the study was equations to reliably predict concentrations and emission rates of key airborne pollutants (Banhazi *et al.*, 2008b; Banhazi *et al.*, 2008c; Banhazi *et al.*, 2008d; Banhazi *et al.*, 2008a). Later on the models developed were fine-tuned and validated using an innovative statistical approach (Banhazi *et al.*, 2010).

DISCUSSION OF KEY STUDY RESULTS

General comments on concentrations and emissions measured

This study delivered a number important outcome. First of all, the validated model developed can be used as a practical management tool to predict the concentrations and emissions of major pollutants without undertaking costly measurements. Routine use of the combined predictive model is expected to make pig producers aware of potential problems associated with air quality on their farms. In turn, this will facilitate the inclusion of pollutant abatement techniques into routine management procedures on farm, improving the health and welfare of pigs and piggery workers as well as the environmental sustainability of piggery operations. Furthermore, designing piggery buildings to minimize airborne pollution now is a theoretical possibility. Using the predictive equations, mathematical optimization of building and engineering parameters will be possible in order to minimize the concentrations and emissions of different airborne pollutants. The optimization process could calculate the best combination of building features to achieve minimum pollutant loading internally and externally. Such calculation would be very useful for building companies as well as for individual producers contemplating building renovations. These "low-pollution" buildings could improve piggery environment for the benefits of both pig and piggery staff and could reduce the environmental impact of piggery operations. In addition, if reliable economical data on the effects of airborne pollutants becomes available, the potential financial advantage of one building design over another could be predicted. The range of pollutant concentrations measured in the study buildings are presented and compared to European concentration values in Table 1.

Table 1: Mean concentrations of key airborne pollutants measured in Australian piggery buildings (based on building averages) (Banhazi *et al.*, 2008c)

Pollutant	*Concentrations suggested in Australia*	*Australian study*
Ammonia (ppm)	10	3.7
Inhalable particles (mg/m^3)	2.4	1.74
Respirable particles (mg/m^3)	0.23	0.26
Respirable endotoxins (EU/m^3)	50	33
Total airborne bacteria (10^5 cfu/m^3)	1.0	1.17

Recommendations for airborne pollutant concentration targets in livestock buildings in Australia are available and the study demonstrated that the average airborne pollutant concentrations in piggery buildings in Australia are generally below or near the recommended limits. Australian piggery buildings generally have lower or comparable airborne pollutant concentrations compared to published results from Europe (Seedorf *et al.*, 1998; Takai *et al.*, 1998; Groot Koerkamp *et al.*, 1998). Atmospheric NH_3 concentration on average is not a major concern in Australian buildings, as ventilation rates are much higher compared to buildings in colder regions of the world, such as parts of Europe or North America. Only 1% of the buildings surveyed had concentrations measured above recommended levels for CO_2 and approximately 8% of buildings were above the recommended 10 ppm concentrations. The concentrations of airborne particles were high in deep-bedded shelters (DBS); the mean concentration of endotoxin, total bacteria, inhalable and respirable particle concentrations exceeded the recommended limits frequently (Banhazi *et al.*, 2008c). Pigs housed in DBS and workers undertaking manual tasks in those buildings were potentially exposed to high concentrations of these airborne pollutants. In the absence of more specific information, the concentrations measured in DBS do provide a ground for concern.

Factors affecting concentrations and emissions

A number of individual models were developed during the study to explain the variation observed in the concentrations and emission of the airborne pollutants, as well as in environmental variables. Table 2 summarizes all significant main effects identified for the concentrations and emissions of the five major airborne pollutants measured during the study.

Table 2. Significant effects associated with the concentrations and emission rates of the five major airborne pollutants measured.

Concentration	Ammonia	Airborne Bacteria	Respirable Endotoxin	Respirable Particles	Inhalable Particles
		Building type	Building type	Building type	Building type
	Cleanliness	Cleanliness		Cleanliness	
	Management			Management	Management
	Seasons			Seasons	Seasons
	Shed size				Shed size
				Ventilation	Ventilation
				Temperature	Temperature
			Humidity	Humidity	
				Sow number	Sow number
Emission		Ventilation type	Ventilation type	Ventilation type	Ventilation type
		Inlet height	Inlet height	Inlet height	Inlet height
		Building height		Building height	Building height
	Building type			Building type	Building type
	Temperature			Temperature	
	Humidity				Humidity
	Management			Management	
	Seasons				Seasons
					Building width
		Cleanliness			
	Sows number				

The concentrations of four airborne pollutants were affected by the classification of the buildings. Three pollutant concentrations were affected by cleanliness, management and seasons, while the concentrations of two pollutants were affected by temperature, humidity, ventilation, sow numbers and shed size (Table 2). The emission rates of four airborne pollutants were affected by the classification of the ventilation system and the height of the air inlets. Three pollutant emission rates were affected by the type and height of the buildings. The emission rates of two airborne pollutants were affected by temperature, humidity, management and seasons. The emission rate of one pollutant was affected by building width, pen hygiene and sow numbers (indication of farm size) (Table 2). In general, the statistical analysis accurately identified the important factors affecting the concentrations and emissions of major airborne pollutants and therefore improved the understanding of the behaviour of those pollutants. In the section below, the primary building and management effects identified during the study are discussed.

Type of buildings

The type of building (dry sow, farrowing, weaner, grower/finisher buildings and DBS) had a highly significant effect on total bacteria, respirable endotoxin, inhalable and respirable particle concentrations and on the emissions of NH_3, inhalable and respirable particles (Banhazi *et al.*, 2008c; Banhazi *et al.*, 2008a). Overall, DBS recorded the highest concentrations for all four pollutants. Inhalable particle emission was the highest from weaner buildings and from DBS (Banhazi *et al.*, 2008a). It was hypothesised that the presence of bedding material in DBS is a risk factor for the high particle concentrations and high inhalable particle emissions under Australian climatic conditions. Similar findings were reported by European researchers for cattle buildings (Takai *et al.*, 1998). DBS were also implicated in generating very high endotoxin, airborne bacteria, inhalable and respirable particles emission rates (Banhazi *et al.*, 2008a). Other types of buildings had relatively small emissions when compared to DBS. The high emissions from DBS are a concern in terms of environmental sustainability and appropriate reduction methods should be investigated. It has been demonstrated that increased humidity appeared to decrease particle concentrations in and emissions from DBS (Banhazi *et al.*, 2008c; Banhazi *et al.*, 2008a). The increased humidity levels would make the bedding material more adhesive, trapping smaller particles within the larger fibres of the bedding material, reducing both concentrations and therefore emissions of respirable particles from these type of structures. However increasing humidity would not be advised as a management tool, as it can compromise thermal comfort of animals in both summer and winter. Therefore, implementation of treatments, which will not increase humidity but result in increasing the adhesion of bedding material used, should be considered in DBS.

Pen hygiene and pig flow management

The effect of pen floor hygiene (essentially pen cleanliness) on airborne bacteria, NH_3 and respirable particle concentrations was an important finding of the study and partially confirmed the results of previous studies on air quality (Aarnink *et al.*, 1997; Ni *et al.*, 1999). Dunging patterns need to be controlled in order to improve pen hygiene. It is interesting to note that while hygiene was an important factor in concentrations of airborne pollutants, it only influenced emission of bacteria. All-in/all-out management proved to be beneficial for reducing the concentrations of NH_3. Management interacted with seasons for NH_3, indicating that summer in continuous flow (CF) buildings is a risk factor for high NH_3 concentrations. These findings confirmed the results of Dutch researchers, reporting on the strong influence of temperature on incorrect dunging behaviour in pigs.

Season

The effects of season on the concentration of various airborne pollutants were complex and varied for different airborne contaminants. In piggery buildings, an increase in the concentrations of inhalable particles has been demonstrated in this study for the winter period. However, for smaller particles, the turbulence associated with higher air velocities associated with summer conditions, could increase respirable particle concentrations under certain conditions. Higher concentrations of NH_3 and significantly higher emission rates were recorded in summer than in winter in CF management system but not in buildings managed on an AIAO basis. Therefore, it can be concluded that while winter is a risk factor for inhalable particles, in summer greater emphasis needs to be placed on reducing potentially high NH_3 and respirable particle concentrations.

Ventilation related factors

Factors related to the operation of ventilation systems have been demonstrated to have a very significant influence on emission rates (Banhazi *et al.*, 2008d; Banhazi *et al.*, 2008a). The emission rates of all pollutants (with the exemption of NH_3 emission) were influenced by the size of ventilation inlet opening. Airborne bacteria, respirable endotoxin, inhalable and respirable particles emission rates are all increased with increasing size of air inlets. The classification of ventilation systems also had a very significant influence on emission rates. Airborne bacteria, respirable endotoxin, inhalable and respirable particles emission rates were the highest from tunnel-ventilated buildings, which is a typical feature of DBS. The high emission rates observed for these pollutants were partially related to high internal concentrations measured typically in DBS (Banhazi *et al.*, 2008c; Banhazi *et al.*, 2008d; Banhazi *et al.*, 2008a).

Temperature and humidity

Generally, temperature had a positive correlation with both inhalable and respirable particles concentrations and emission. As temperature increases, piggery buildings tend to become a drier environment, creating greater opportunities for particle generation (Pedersen *et al.*, 2001). Because of increased temperature, respirable particle concentrations increased significantly in AIAO buildings. Inhalable particle concentrations were also significantly affected by temperatures, but the relationship was more complex due to interaction with the classification of the buildings. The effect of humidity interacted with building type for respirable particles and there was a pronounced reduction effect of increased humidity in DBS. Increased humidity also sharply reduced respirable particle emissions from DBS and NH_3 emission generally. However, for other building types the effect of humidity was not simple and in interaction with management type, demonstrated a positive correlation with respirable particle concentrations. This study also found that humidity affected endotoxin concentrations (Banhazi *et al.*, 2008c). This finding could have implications for dust reduction methods, such as spraying of oil/water mixture.

Farm size

The size of farm (as described by the number of sows) had a significant effect on both inhalable and respirable particle concentrations. Inhalable particle concentrations were strongly and positively associated with sow numbers. However, the effect of sow number on respirable dust was more complex. It has been hypothesized that on larger farms, due to work pressures, less time is available for cleaning and general maintenance of the environment of the pigs. Therefore, the reduced hygiene and increased intervals between cleaning episodes creates an ideal environment for higher dust concentrations in buildings on large corporate farms (Banhazi *et al.*, 2008c). (Banhazi *et al.*, 2008c)

CONCLUSIONS

This study demonstrated that compromised pen hygiene is an important risk factor for elevated concentrations of NH_3, viable and non-viable particles. The effect of housing type was greatest on a number of pollutants, however applying improved management of these buildings is more readily applicable. Therefore, this source of airborne pollution could be eliminated to a large extent by controlling dunging patterns and improving the hygienic conditions of pens. The current practice of managing buildings using all-in/all-out strategy with thorough cleaning of the facilities between batches of pigs is advisable. Treatment of bedding materials in DBS is highly advisable to reduce the opportunities for particle generation. The knowledge generated by this study will also enable piggery managers to focus on reducing the concentrations of specific pollutants under different seasonal conditions. Ventilation, humidity and temperature can be theoretically adjusted to minimize airborne pollution emission and concentration in piggery buildings. In terms of emission rates, it appears that ventilation related factors have the most influence on the amount of airborne pollutants emitted from piggery buildings. Although, some of the management methods suggested might be successfully used to reduce the concentration and potentially the emission rates of airborne pollutants, in reality there are limitations associated with managing emission rates via concentration reduction. Therefore, the immediate focus has to be on developing new techniques and evaluating existing ones (such as air scraping and bio-filters), which have the capacity of capturing emitted pollutant plumes from livestock buildings.

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